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TIMING OF NITROGEN APPLICATION TO GRASSLAND IN SPRING; A CRITICAL EVALUATION OF THE APPLICABILITY OF THE "DUTCH" METHOD IN THE UK

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Introduction

Various solutions have been suggested to the problem of optimising the timing of nitrogen application to grassland in spring. One of these is the so-called "Dutch" method, which involves calculating accumulated air temperatures above 0°C from the first of January until 200 day degrees C have been accumulated (van Burg, 1977). In the Netherlands grassland farmers are advised to apply their spring nitrogen when this point is reached in a particular season, and it is said to coincide with the "start of growth". Apparently no account is taken of current or of predicted temperatures for the next few days.

However, it has been shown in experiments at the Grassland Research Institute and elsewhere that if growth is measured as the rate of leaf extension, then it appears to be predominantly a function of the grass species and variety, of whether a tiller is vegetative or reproductive, and of the growing point temperature at that time (Peacock, 1975a, 1975b, 1975c, 1976, Robson et al, 1978), and can vary considerably from day to day depending on temperature changes (Figure 1). It is difficult to envisage how growth can start when a 200 day degree total may be reached at a time when current average temperatures may be only just above freezing point. (Since the response to temperature shows a gradual increase from very low leaf extension rates at temperatures close to freezing point it is equally invalid to say that growth starts at, say, 5°C or 6°C).

The 200 day degree criterion may have some validity if it is used to indicate that sufficient root growth will have already taken place to ensure that the grass is able to take up any applied nitrogen from the soil, without there being an appreciable risk of leaching occurring. However, there would have to be a monitoring of current soil temperatures and if the date occured very early in the year serious consideration would have to be given to the desirability of applying nitrogen at that time. This is in fact a major problem in the UK where winters are considerably milder than in the Netherlands.

A comparison of temperatures at representative inland and coastal sites in the UK and the Netherlands (Figures 2a and 2b) shows that average air temperatures are generally considerably higher in the UK except in upland areas. For example during the winter period from December to February, Buxton at 307m is on average warmer than De Bilt at 3m, and Wick at 58½°N is warmer than Vlissingen at 51½°N.

However, the average rate of rise in temperature in spring is much lower in the UK than in the Netherlands due to the much stronger maritime influence. Consequently the acceleration in growth during this period is much less, and mild weather early in the year is frequently followed by much colder spells.

200 day degree C dates in the UK

Daily archive weather datawere available for a large number of climatological stations (including official Meteorological Office observing stations)from either 1957 or 1959, depending on the type of station, and most of the analyses covered the period 1958-77 or 1959-77, with the dates for 1979 being also obtained

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for comparison with 1963. However, in order to investigate the characteristics of the frequency distributions it was desirable to analyse longer-period temperature data for Plymouth (1931-78), Cardiff (1913-76) and Bradford (1908-78).

The long-period data showed that, as would be expected, the frequency distribution of D, the day number of the date in each year when the accumulated temperature above 0°C from 1 January reached 200 day degrees C, was positively skew. However, a transformation of the form $T_D = 200/D$ gave distributions which were not significantly different from normal, and gave good agreement with the median and upper and lower quartiles of the original data (Tables 1a, 1b). For these three stations it was also found that the medians for the recent 1958-77 period were quite close to those for the full period available.

Figure 3 shows the locations of the 24 stations used for calculation of D dates for the recent period and the median dates obtained using the relation $D_{median} = 200\ T/_{D}$. Table 2 shows the results in more detail and gives the quartile dates calculated from the mean and standard deviation of T_D.

The dates obtained show that for most of the lowland sites the 200 day degree C total was attained before the last week in February in half of the years in the sample and before the middle of February in a quarter of the years. In the "early" areas of southwest England the median date occurred at the beginning of February.

As far as very late years were concerned, the winter and early spring of 1963 were colder than those of 1979 in southern England and the southern half of Wales, and about the same in both years in central England and north Wales. However, 1979 was colder than 1963 in northeast England and eastern Scotland.

Discussion

The 200 day degree criterion would indicate much earlier dates for spring application of nitrogen to grassland than those which are current practice in the UK. Among the questions which arise as a consequence of this are;

1) Do these dates really indicate the time at which grass plants become more able to utilise any applied nitrolgen?

2) What response to applied nitrogen can be expected in terms of dry matter produced per kg nitrogen applied at, say, the 200 day degree C date, and how much does this depend on the subsequent weather conditions? How much nitrogen is likely to be lost by leaching?

3) What is the likelihood of ground conditions being suitable for nitrogen to be applied without the risk of serious damage to the sward?

The answer to the first question can only be obtained from trials in the field and/or controlled environments in which the movement of nitrogen in the soil and in the plants is closely monitored, together with changes in soil and air temperatures and water movement.

TABLE 1a

DISTRIBUTIONS OF NUMBER OF DAYS TO REACH AN ACCUMULATION OF 200 DAY DEGREES C (D) AND EFFECTIVE MEAN TEMPERATURE DURING THAT PERIOD T_D = 200/D FOR BRADFORD, CARDIFF AND PLYMOUTH

D	BRADFORD 1908-78	CARDIFF 1913-76	PLYMOUTH 1931-78
Mean	56.3	43.0	34.6
Standard deviation	16.57	13.15	9.20
Coefficient of skewness	0.691	1.351	2.043
T_D			
Mean	3.85	5.00	6.09
Standard deviation	1.097	1.240	1.271
Coefficient of skewness	0.496	-0.200	-0.266

TABLE 1b

OBSERVED AND CALCULATED VALUES FOR QUARTILE BOUNDARIES OF D, ASSUMING A NORMAL DISTRIBUTION FOR T_D

	BRADFORD	CARDIFF	PLYMOUTH
Lower quartile			
Observed	13 February	3 February	29 January
Calculated	13 February	3 February	29 January
Median			
Observed	22 February	9 February	2 February
Calculated	21 February	9 February	2 February
Upper quartile			
Observed	6 March	17 February	7 February
Calculated	5 March	17 February	7 February

TABLE 2

DISTRIBUTIONS OF DATES ON WHICH AN ACCUMULATION OF 200 DAY DEGREES C FROM 1 JANUARY WAS REACHED FOR 24 OBSERVING STATIONS IN THE UK.

Station	Height in m	Years	Earliest	Lower Quartile	Median	Upper Quartile	Latest	1979
Wick	36	58-77	8/2/71	15 FEB	22 FEB	3 MAR	19/3/63	30 MAR
Kinloss	5	58-77	8/2/74	15 FEB	22 FEB	3 MAR	20/3/63	30 MAR
Dyce	58	58-77	15/2/71	22 FEB	1 MAR	10 MAR	31/3/63	2 APR
Turnhouse	35	58-77	3/2/74	13 FEB	20 FEB	2 MAR	23/3/63	26 MAR
Prestwick	16	58-77	2/2/75	9 FEB	15 FEB	23 FEB	21/3/63	22 MAR
Loughgall	25	59-77	1/2/74	7 FEB	13 FEB	21 FEB	17/3/63	12 MAR
Cockle Park	99	58-77	11/2/75	19 FEB	26 FEB	6 MAR	2/4/63	7 APR
High Mowthorpe	175	59-77	16/2/74	25 FEB	4 MAR	15 MAR	11/4/63	13 APR
Carlisle	26	61-77	1/2/75	10 FEB	16 FEB	25 FEB	24/3/63	25 MAR
Squires Gate	10	58-77	30/1/75	9 FEB	14 FEB	22 FEB	24/3/63	21 MAR
Shawbury	72	58-77	31/1/75	10 FEB	17 FEB	25 FEB	29/3/63	29 MAR
Waddington	68	58-77	2/2/75	14 FEB	21 FEB	3 MAR	2/4/63	1 APR
Watnall	117	58-77	3/2/75	14 FEB	21 FEB	2 MAR	1/4/63	1 APR
Santon Downham	25	59-77	1/2/75	14 FEB	21 FEB	3 MAR	29/3/63	26 MAR
Gorleston	4	58-77	31/1/75	8 FEB	15 FEB	23 FEB	3/4/63	21 MAR
Rothamsted	128	58-77	2/2/75	14 FEB	21 FEB	3 MAR	2/4/63	31 MAR
Gatwick	59	59-77	31/1/75	10 FEB	17 FEB	25 FEB	27/3/63	19 MAR
Aberporth	134	58-77	29/1/75	3 FEB	7 FEB	12 FEB	20/3/63	9 MAR
Long Ashton	51	58-77	29/1/74	4 FEB	8 FEB	15 FEB	23/3/63	13 MAR
St Mawgan	103	58-77	26/1/74	29 JAN	2 FEB	7 FEB	14/3/63	22 FEB
Exeter	32	58-77	27/1/74	1 FEB	5 FEB	10 FEB	20/3/63	6 MAR
Bradford	134	58-77	1/2/75	15 FEB	23 FEB	6 MAR	1/4/63	5 APR
		08-78	29/1/16	13 FEB	21 FEB	5 MAR	8/4/47	
Cardiff	62	58-76	28/1/76	3 FEB	8 FEB	15 FEB	25/3/63	-
		13-76	26/1/16	3 FEB	9 FEB	17 FEB	25/3/63	
Plymouth	27	58-77	24/1/76	28 JAN	1 FEB	6 FEB	15/3/63	23 FEB
		31-78	23/1/32	29 JAN	2 FEB	7 FEB	15/3/63	

There appear to have been very few field experiments in the early wetter areas which can assist in answering the second question. Murphy (1977) has summarised some results on yields of spring grass obtained at Wexford, in the southeast of Eire, with different dates of nitrogen application in the winter and early spring. However, the paper did not specify the actual seven years whose results were quoted, not did it give any weather data for those years. Although in certain years a significant increase in dry matter was obtained with January application dates as compared with later ones, the response in terms of kg dry matter per kg applied N were generally low for a mid to late April harvest. For a high application rate of over 100kg N per hectare they were of the order of 8kg dry matter per kg N applied, while for an application rate of around 50 kg N per hectare they were about 12 kg dry matter per kg N applied. Some of the nitrogen may of course still have been available for a subsequent growth period. As shown in the Grassland Manuring Trials (Morrison et al, 1979) nitrogen responses during the main part of the growing season can be expected to average over 20 kg dry matter per kg N so that there seems to be little justification in making very large nitrogen applications very early in the year.

Leaching losses can be expected to be related to the total excess rain (defined as rainfall minus transpiration during periods when soils are at field capacity) after the date of nitrogen application, but they will also depend on the soil type and structure. Some of the results which have been obtained using a model of grass growth and soil water conditions could be used to estimate the excess rain each year between the 200 day degree C date and the end of March at St Mawgen (table 3) and Dyce. At St Mawgan the average amount of excess rain was 107mm, but it varied from 39 mm in 1961 to 216 mm in 1977. At Dyce the average total to 31 March was only 29 mm, due partly to the later starting dates, but also to the lower March rainfall. The highest value at Dyce was 117 mm in 1964. By April transpiration is much more closely in balance with rainfall and in general excess rainfall for that month is quite small except in very high rainfall areas.

The effect of subsequent cold weather on nitrogen uptake and the possibility of lush grass showing greater susceptibility to winterkill (as occurred in 1969) also need to be investigated before a recommendation for optimum nitrogen application dates can be devised. Table 4 gives a comparison of the 200 day degree C dates for the Netherlands (as given in van Burg, 1977) with those for St Mawgan, Gatwick and Waddington for the same years. It should be noted that in certain years (e.g. 1959,1960) dates were very similar in the Netherlands and in eastern England, but that in 1962, 1964, 1969 and 1970 they were much earlier in the UK. In all of the latter years March was cold or very cold and frequently wet, so that an early apparent start to growth in January or February was followed by a severe setback later on.

TABLE 3

ESTIMATED EXCESS RAIN AT ST MAWGAN FROM DATE OF REACHING 200 DAY DEGREES C UNTIL 31 MARCH

Year	Date of reaching 200 day degrees C	Excess rain in mm
1958	2 February	152
1959	9 February	80
1960	1 February	130
1961	3 February	39
1962	31 January	66
1963	14 March	62
1964	4 February	106
1965	10 February	41
1966	3 February	145
1967	1 February	113
1968	30 January	52
1969	28 January	91
1970	31 January	103
1971	29 January	84
1972	5 February	135
1973	2 February	75
1974	26 January	216
1975	26 January	100
1976	27 January	194
1977	6 February	157
Average		107

TABLE 4

DATES OF REACHING AN ACCUMULATED TEMPERATURE FROM 1 JANUARY OF 200 DAY DEGREES C IN NETHERLANDS AND AT THREE STATIONS IN THE UK

Year	Netherlands	St Mawgan	Gatwick	Waddington	Comments for UK
1959	early March	9 Feb	1 Mar	3 Mar	Mild, fairly wet spring after dry Feb.
1960	late Feb	1 Feb	21 Feb	28 Feb	Mild, average March rainfall.
1961	late Feb	3 Feb	12 Feb	17 Feb	Very mild spring, dry March.
1962	mid March	31 Jan	12 Feb	13 Feb	Very cold from 22 Feb to late March.
1963	early April	14 Mar	27 Mar	2 Apr	Very cold until early March.
1964	late March	4 Feb	26 Feb	28 Feb	Cold, very wet March.
1965	mid March	10 Feb	7 Mar	8 Mar	Cold, rather wet March, warm at end.
1966		3 Feb	17 Feb	26 Feb	Very wet Feb, dry March.
1967		1 Feb	14 Feb	18 Feb	Mild, rather wet Feb & March.
1968		30 Jan	28 Feb	4 Mar	Cold Feb, dry Feb and March.
1969	early April	28 Jan	18 Feb	5 Mar	Very cold after Jan, rather wet.
1970	mid April	31 Jan	19 Feb	10 Mar	Very cold March and April, rather wet.
1971	late Feb	29 Jan	13 Feb	14 Feb	Mild, dry Feb, but severe frosts around 16th.
1972	mid March	5 Feb	16 Feb	24 Feb	Mild Feb and March, wet in south.
1973	early March	2 Feb	19 Feb	12 Feb	Average temps., dry spring.
1974	early/mid Feb	26 Jan	2 Feb	10 Feb	Mild Feb very wet Feb up to 17th.
1975	early Feb	26 Jan	31 Jan	2 Feb	Mild, dry Feb, cool March, very wet in south.
1976	late Feb	27 Jan	13 Feb	12 Feb	Near average temps., very dry in east.

The Netherland data on the response of yield of dry matter at grazing and cutting stages to the time of nitrogen application included only two years when 200 day degrees C was reached by early February. These were 1974 and 1975, and in both years February was a dry month in the Netherlands (total rainfall at Eelde was 34 mm in 1974 and 20 mm in 1975), so that leaching would not have been expected to be a major problem. The results, (Postmus, 1976), did not show much sensitivity to the time of application until those after early March when the yields started to all off with later dates of application. However, because of the dry weather in February it is not possible to deduce from these trials what might have happened in 1974 and 1975 if the months had been cold and wet.

The question of the feasibility of application at a particular time requires the specification of suitable ground conditions for different soils and types of pasture (temporary ley, well-established permanent grassland), and the machinery involved, including possibly low ground pressure vehicles. Once this has been done archive weather data can be used to calculate possible work days over a period of years.

Conclusions

Before a satisfactory scheme can be devised for the UK for determining the optimum date for applying nitrogen to grassland in spring, a considerable amount of detailed experimental work is required, concentrating on the milder, wetter areas where leaching problems are more likely to be important if early application dates are adopted. These experiments must include the determination of the rate of uptake at different temperatures, the effects of previous temperatures on root and shoot growth and consequent uptake, and losses of nitrogen (including leaching).

However, even if it were possible in retrospect to determine the optimum date for a particular sward for a given purpose for an individual year from weather data, it may be very difficult to give useful advice in a current season if an accurate forecast is needed of the weather in the late winter and spring. Long-range weather forecasting is still far from being able to provide such information. The years in which advice is likely to be most accurate and useful are the ones with cold winters and late springs, while the ones with mild weather early in the year will probably give rise to most problems.

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Robson, M J Parsons, A J Perkins, M A and Woledge, J	1978	Energy, partition and utilization of carbon in grass production. (c) Leaf growth. A. Rep. Grassland Res. Inst. 1977, p. 69

Any comments or suggestions on this paper should be referred to the authors.

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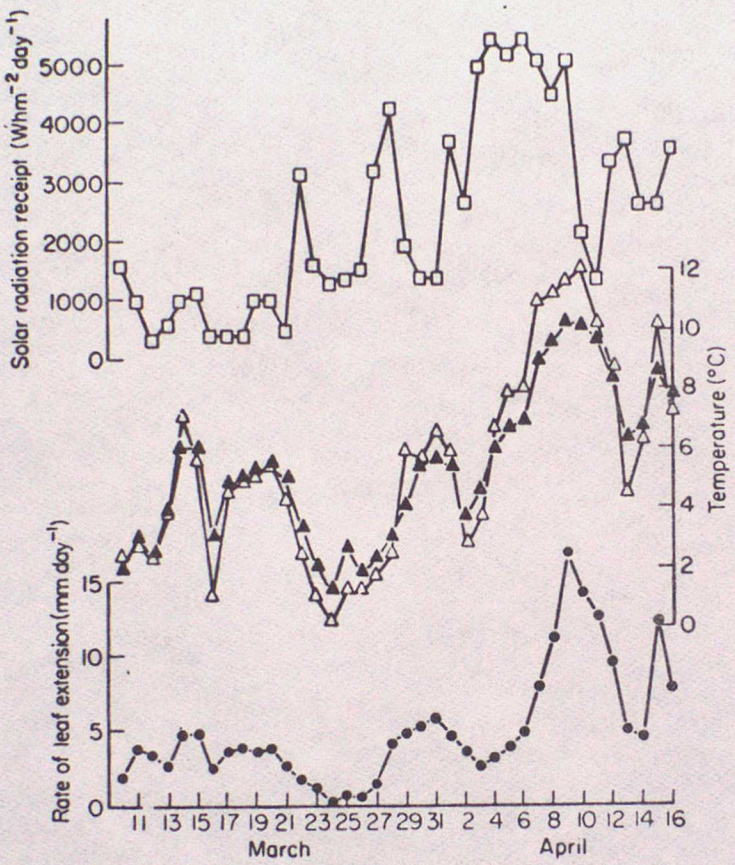
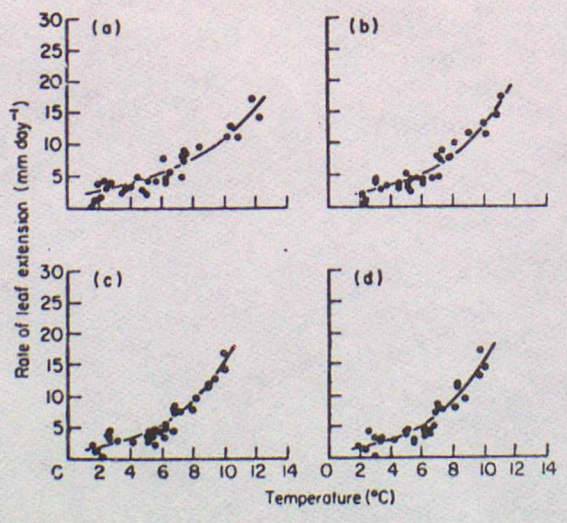
FIG 1

J. M. PEACOCK

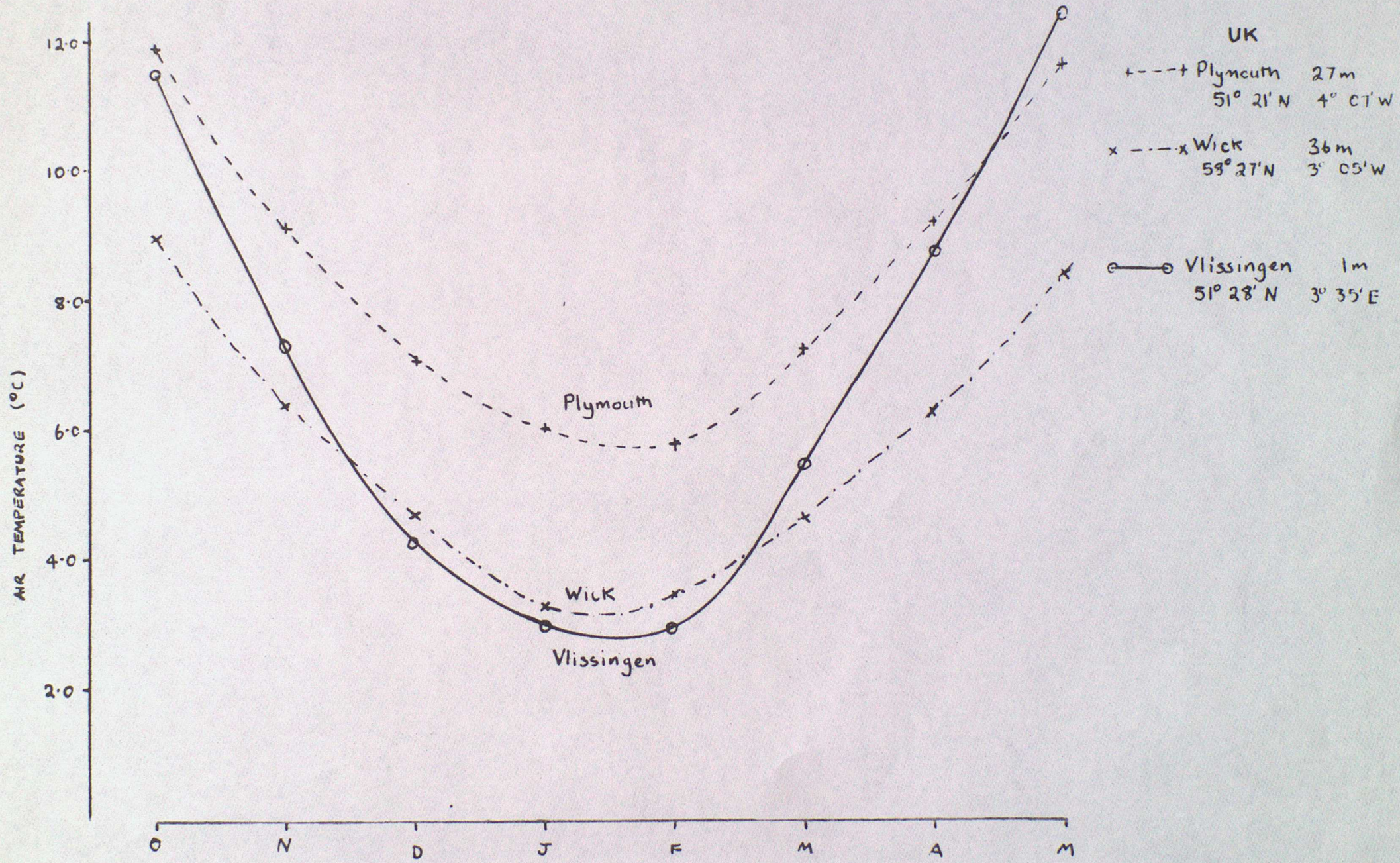


Comparison of the rate of leaf extension, ● of perennial ryegrass (1969), with mean soil, ▲ and air temperature, △ and solar radiation receipt, □.



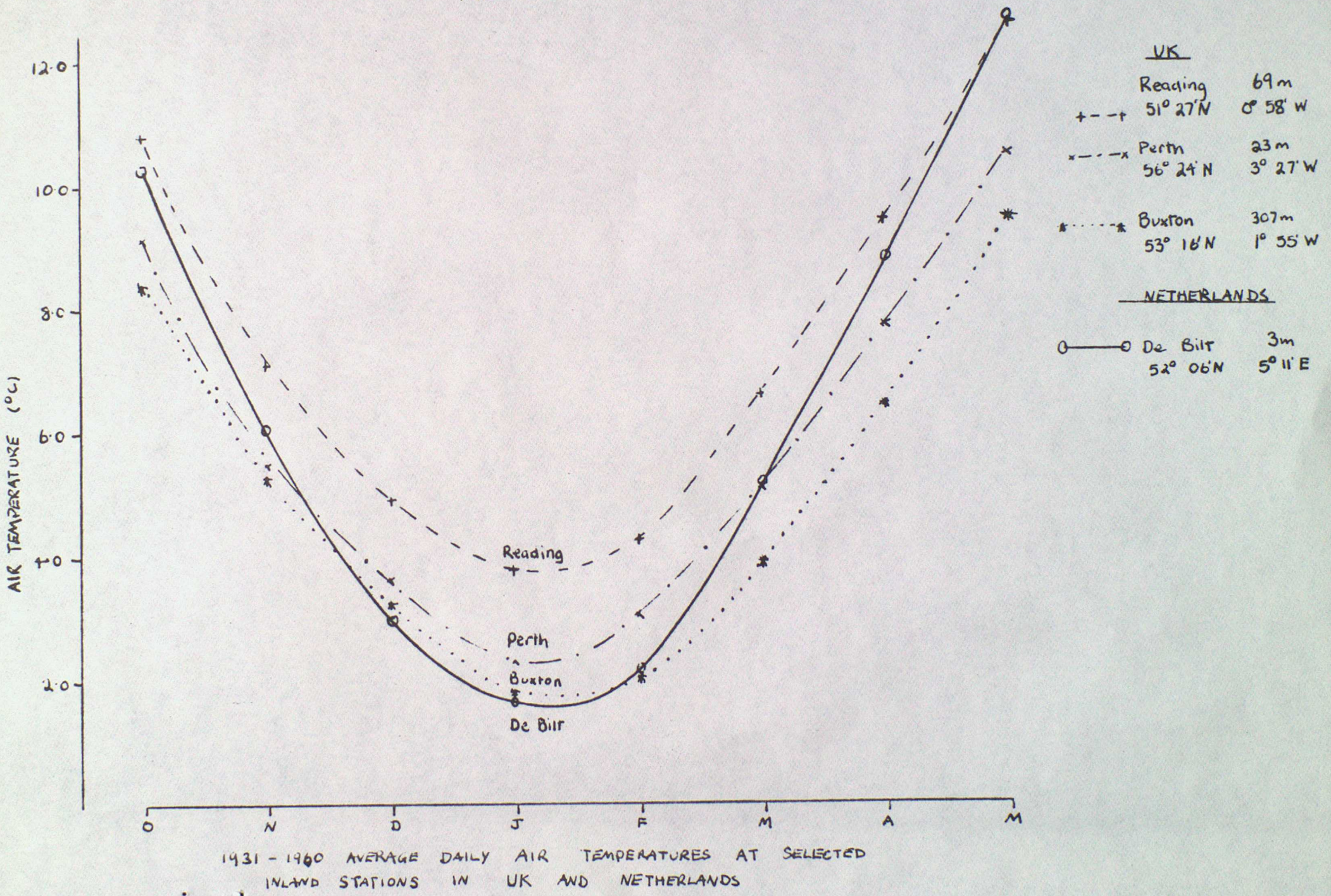
Response curves showing leaf extension of perennial ryegrass (spring 1969) plotted against mean temperature in the plant canopy at (a) 5 cm above the soil surface, (b) the soil surface, (c) 2 cm and (d) 10 cm below the soil surface.

FIG2.

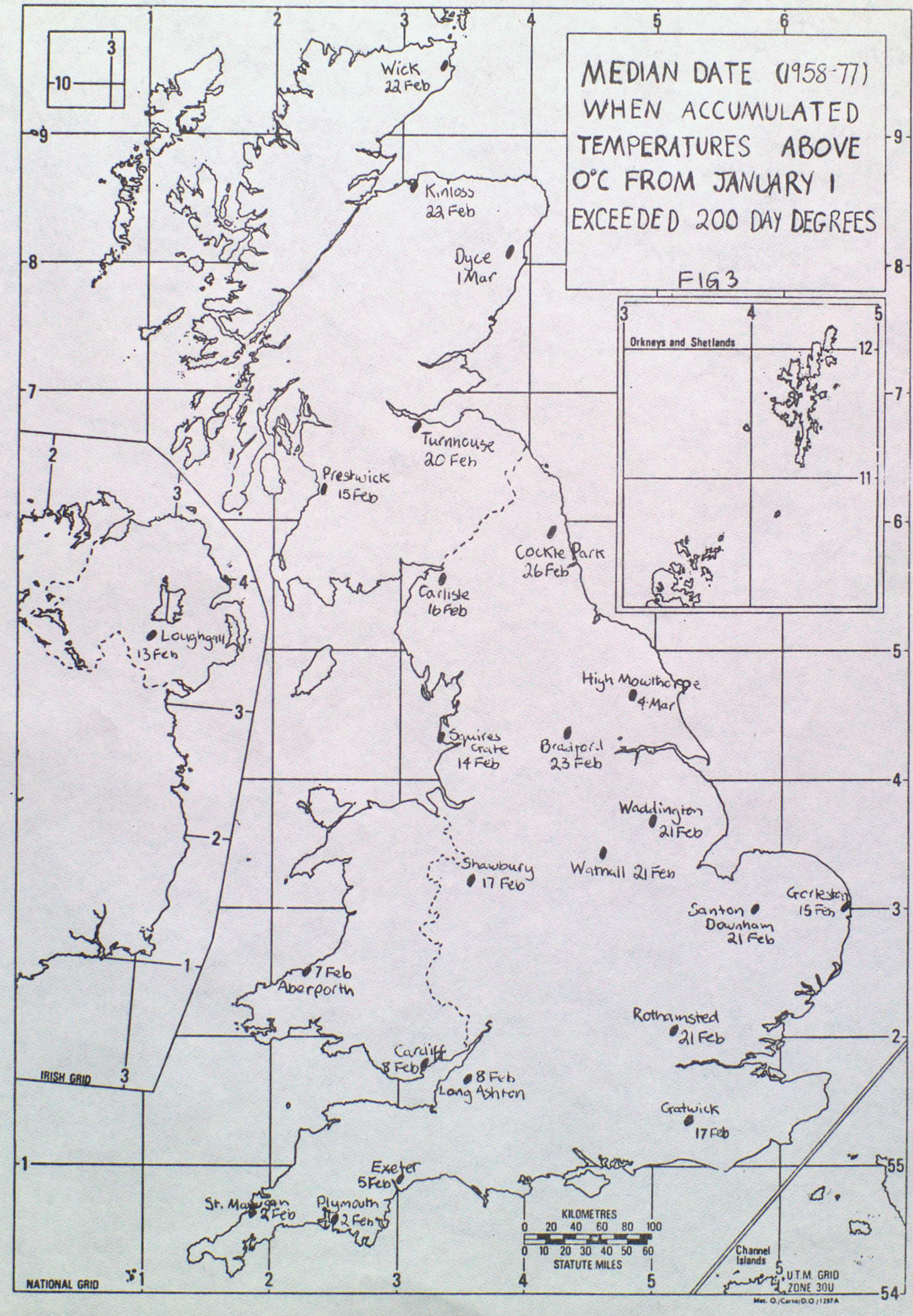


1931–1960 AVERAGE DAILY AIR TEMPERATURES AT SELECTED COASTAL STATIONS IN THE UK AND NETHERLANDS

FIG2b



1931 - 1960 AVERAGE DAILY AIR TEMPERATURES AT SELECTED INLAND STATIONS IN UK AND NETHERLANDS


MEDIAN DATE (1958-77) WHEN ACCUMULATED TEMPERATURES ABOVE 0°C FROM JANUARY 1 EXCEEDED 200 DAY DEGREES
FIG 3
Orkneys and Shetlands
Wick 22 Feb
Kinloss 22 Feb
Dyce 1 Mar
Turnhouse 20 Feb
Prestwick 15 Feb
Cockle Park 26 Feb
Carlisle 16 Feb
Loughgall 13 Feb
High Mowthorpe 4 Mar
Squires Gate 14 Feb
Bradford 23 Feb
Waddington 21 Feb
Shawbury 17 Feb
Watnall 21 Feb
Gorleston 15 Feb
Santon Downham 21 Feb
7 Feb Aberporth
Rothamsted 21 Feb
Cardiff 8 Feb
8 Feb Long Ashton
Gatwick 17 Feb
Exeter 5 Feb
St. Mawgan 2 Feb
Plymouth 2 Feb
Channel Islands
IRISH GRID
NATIONAL GRID
U.T.M. GRID ZONE 30U
KILOMETRES
STATUTE MILES
Met. O./Carto/D.O./1257A